LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA4 | Kilburn (Brent) to Old Oak Common

Old Oak Common breach analysis modelling report (WR-004-001)

Water resources

November 2013

ES 3.5.2.4.14

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Contents

List of figures

List of tables

1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise four parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Kilburn (Brent) to Old Oak Common area (CFA4), these are:

- a water resources assessment (Volume 5: Appendix WR-002-004);
- a flood risk assessment (Volume 5: Appendix WR-003-004); and
- a hydraulic modelling report of a breach of the Grand Union Canal (Paddington Branch) at Old Oak Common (i.e. this appendix).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Scope and structure of this assessment

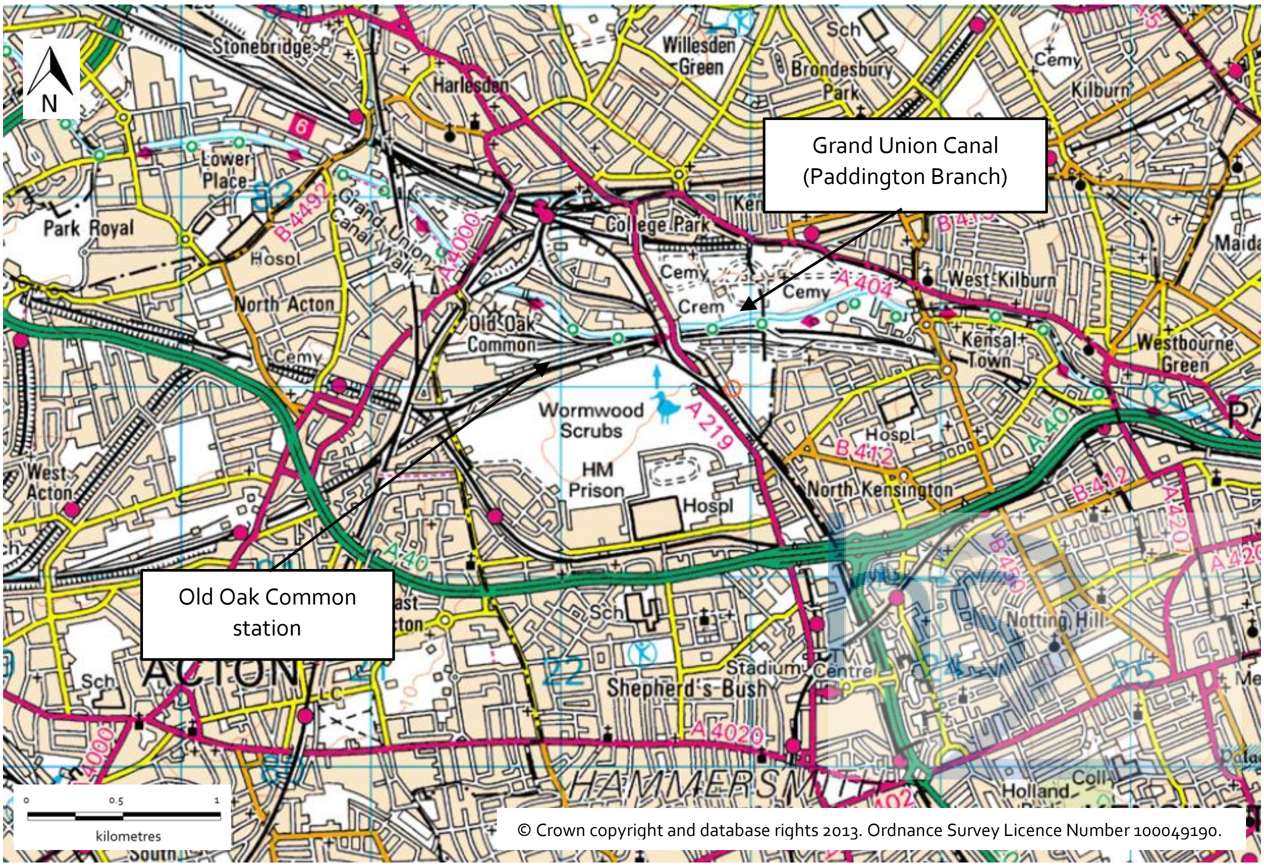
1.2.1 This document presents the hydraulic modelling that was undertaken for a breach of the Grand Union Canal (Paddington Branch) at Old Oak Common. The purpose of the modelling is to support the flood risk assessment.

1.2.2 The location of the model is identified in Section 2. The modelling methodology is set out in Section 3. Section 4 presents the modelling results. Section 5 covers the model validation, Section 6 the conclusions and Section 7 the assumptions and limitations.

2 Location

2.1.1 There is a residual risk of flooding to the proposed Old Oak Common station from failure of the Paddington Branch of the Grand Union Canal to the north of the station. The site is located to the north of Wormwood Scrubs Common, between the urban centres of Acton, Harlesden and Shepherd's Bush, as shown in Figure 1. The Grand Union Canal (Paddington Branch) is retained approximately 5m above the existing rail track level by a vertical retaining structure. A hydraulic model has been created in InfoWorks ICM[1] to model the extent of flooding in the event of a breach of the Grand Union Canal (Paddington Branch). This document presents the details of the model and results.

Figure 1: Location plan of Grand Union Canal (Paddington Branch)



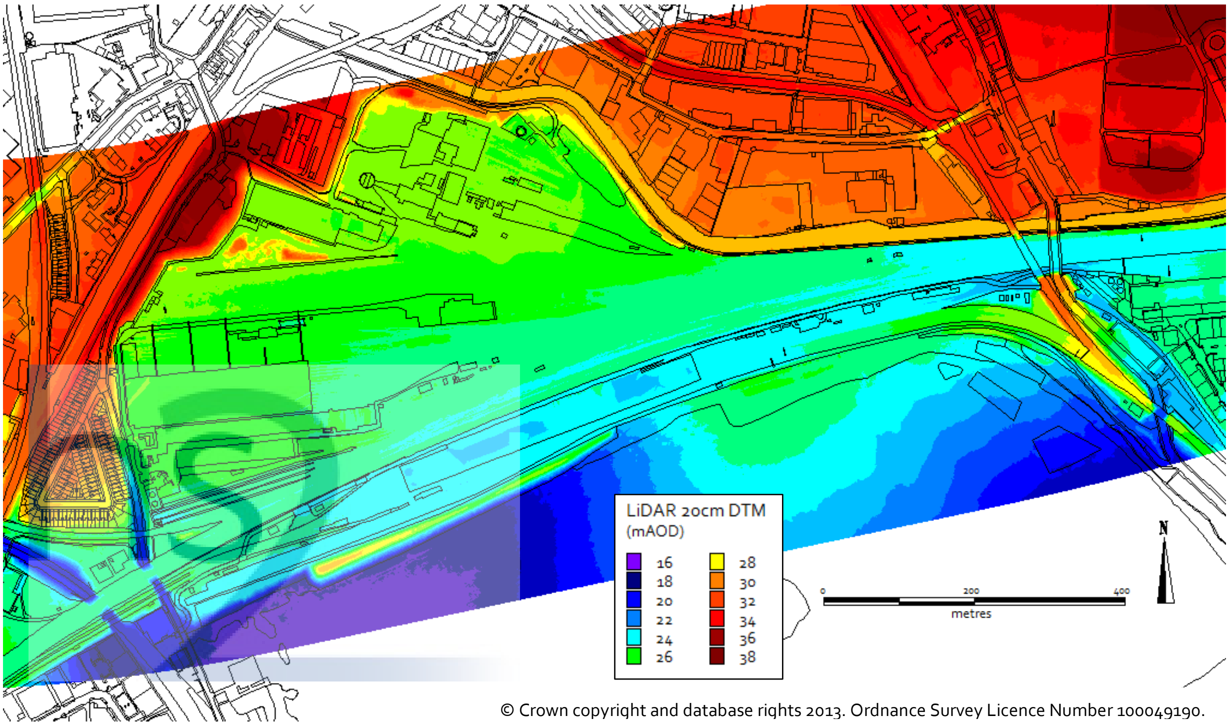
[1] InfoWorks ICM is hydraulic modelling software that utilises both one-dimensional and two-dimensional equations. InfoWorks ICM is published by Innovyze.

3 Methodology

3.1 Model description

3.1.1 The hydraulic modelling was undertaken using InfoWorks ICM. A digital terrain model (DTM) using 20cm light detection and ranging (LiDAR) information was imported into the model with isolated missing ground levels interpolated using MapInfo Discover. A representation of the ground model is shown in Figure 2.

Figure 2: Ground model using a 20cm digital terrain model



3.1.2 The extent of the two-dimensional mesh zone was digitised and refined to ensure that the construction area was included with sufficient mesh element resolution. Existing buildings were removed from the mesh as voids. Roughness zones were digitised using Ordnance Survey (OS) MasterMap. Values of roughness were categorised between rail areas (using a Manning's 'n' of 0.033)[2], the Crossrail Old Oak Common worksite (using a Manning's 'n' of 0.015) and Wormwood Scrubs Common (using a Manning's 'n' of 0.035). A 'normal' depth boundary condition was used at the extent of the mesh. A terrain variable mesh size was used to concentrate calculations at critical locations where the change in topography was greatest. Infiltration was not applied to the model.

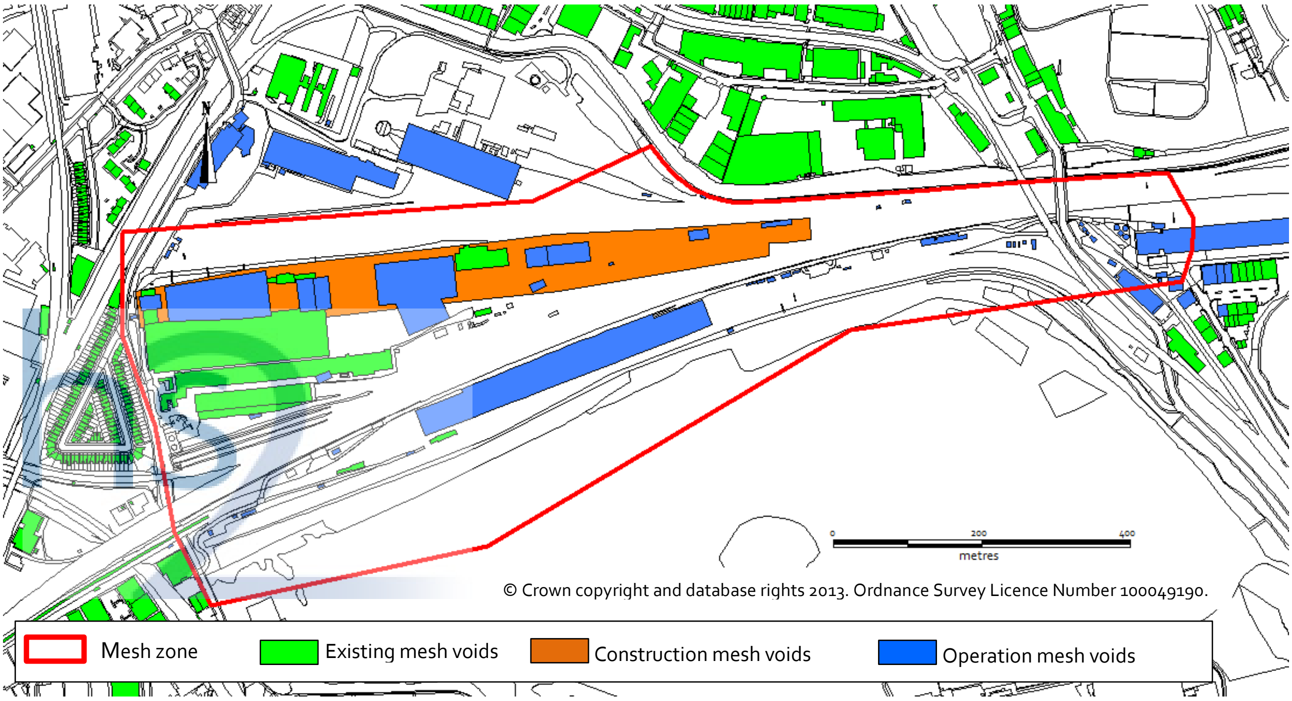
3.1.3 Three models have been used for the breach of the Grand Union Canal at Old Oak Common. The first model represents the existing condition with the Crossrail Old Oak Common worksite, the existing buildings associated with the Great Western Main Line (GWML) and the North Pole International Rail Depot. A second model represents the temporary effects during the construction phase with the excavated area for the

[2] Chow (1959), *Open Channel Hydraulics*.

Proposed Scheme station box also represented as a block in the mesh. The extents of the two-dimensional mesh zone were increased to the north to model the flow of water along the northern face of the station box.

3.1.4 A third model was created to represent the permanent case. In this model the station box excavation was restored and permanent structures of the station and ventilation shafts removed as blocks. Ground raising activities surrounding the station building were included using mesh zones set at the proposed ground levels. Figure 3 shows the extent of the two-dimensional mesh zone and also displays the blocks that were removed from the mesh for each of the three models.

Figure 3: Mesh zone extent and voids



3.2 Canal breach hydraulics

3.2.1 The purpose of the model was to demonstrate the overland routing of a breach of the canal retaining structure. The total length of canal that is not controlled by locks at the location of the breach is approximately 42.9km. Assuming that the average depth of the canal is 1.5m (published data[3] states that a draught of 1.23m can be assumed), and that the average width is 19m (based on a limited number of measurements), the total volume of water that can potentially be discharged during a breach is approximately 1,223,000m^3. As a worst-case scenario, it is assumed that the emergency works on the canal are not undertaken during the breach and therefore the entire volume of this stretch of the canal can discharge through the breach.

3.2.2 The hydraulics of canal breaches has been recently examined in more detail, both physically and numerically, primarily due to an increase in the frequency of global

[3] Inland Waterways Association (2013), https://www.waterways.org.uk/waterways/canals_rivers/gu_london_braunston/gu_london_braunston, Accessed 13 February 2013

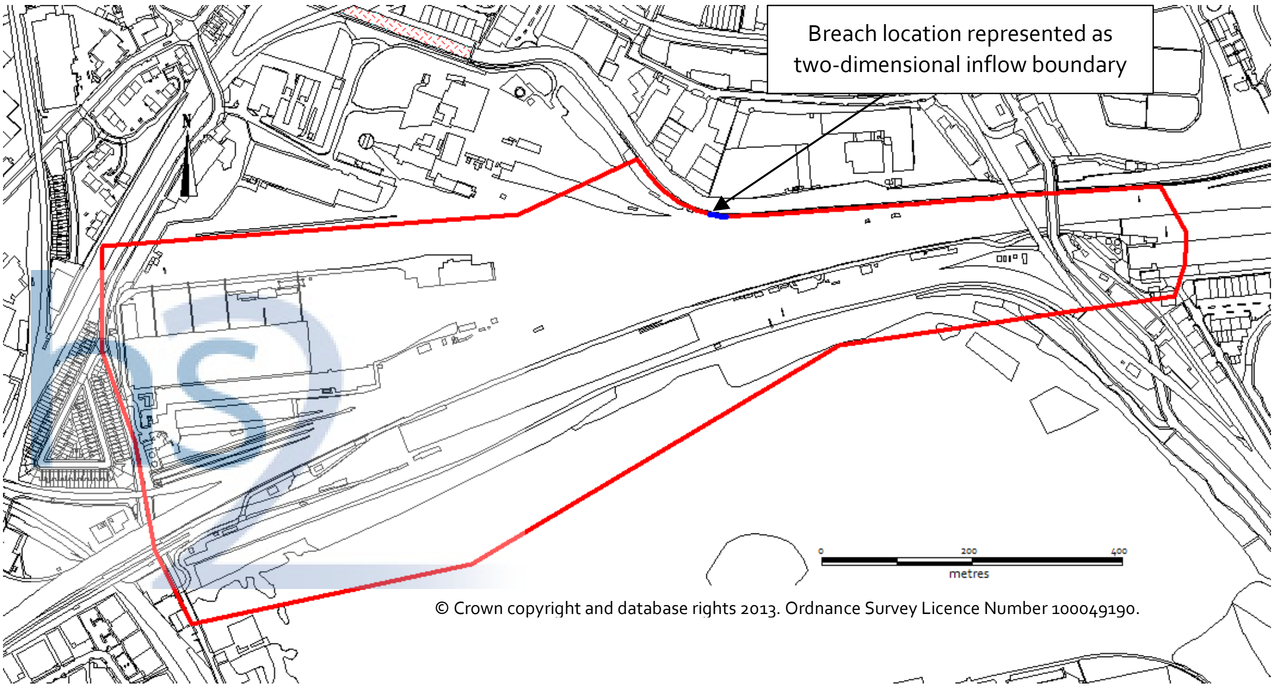
breach incidents. Dun (2005)[4] and Wahl & Lentz (2011)[5] conclude that a breach of a canal retained behind an embankment follows a two stage process:

- discharge is controlled by the geometry of the breach; and
- subsequently it is the channel cross section that becomes the driving influence.

3.2.3 Previous modelling activities have considered the propagation of the breach width as the embankment erodes; in the case of a retaining wall, however, it has been assumed that the breach will not erode in the same way.

3.2.4 The breach was treated conceptually as a broad crested weir. Peak discharge values for varying widths of breach were calculated based on a head behind the weir of 1.5m. The length of the weir was taken to be the width of the towpath between the canal and the retaining wall (4m). Peak discharges were calculated for weir widths of 4m (17m^3/s), 11.75m (50m^3/s) and 20m (85m^3/s). Breach hydrographs were generated with these peak discharges and total flood volumes equivalent to the total breach volume. The inflow hydrographs were applied to the two-dimensional mesh as a two-dimensional inflow boundary at the location of the breach. The assumed worst-case breach location was taken to be on the bend of the retaining wall nearest to the construction site (as shown in Figure 4).

Figure 4: Location of Grand Union Canal (Paddington Branch) breach



3.3 Model simulations

3.3.1 The model runs were undertaken for a two day duration with five minute timesteps for all three discharge hydrographs.

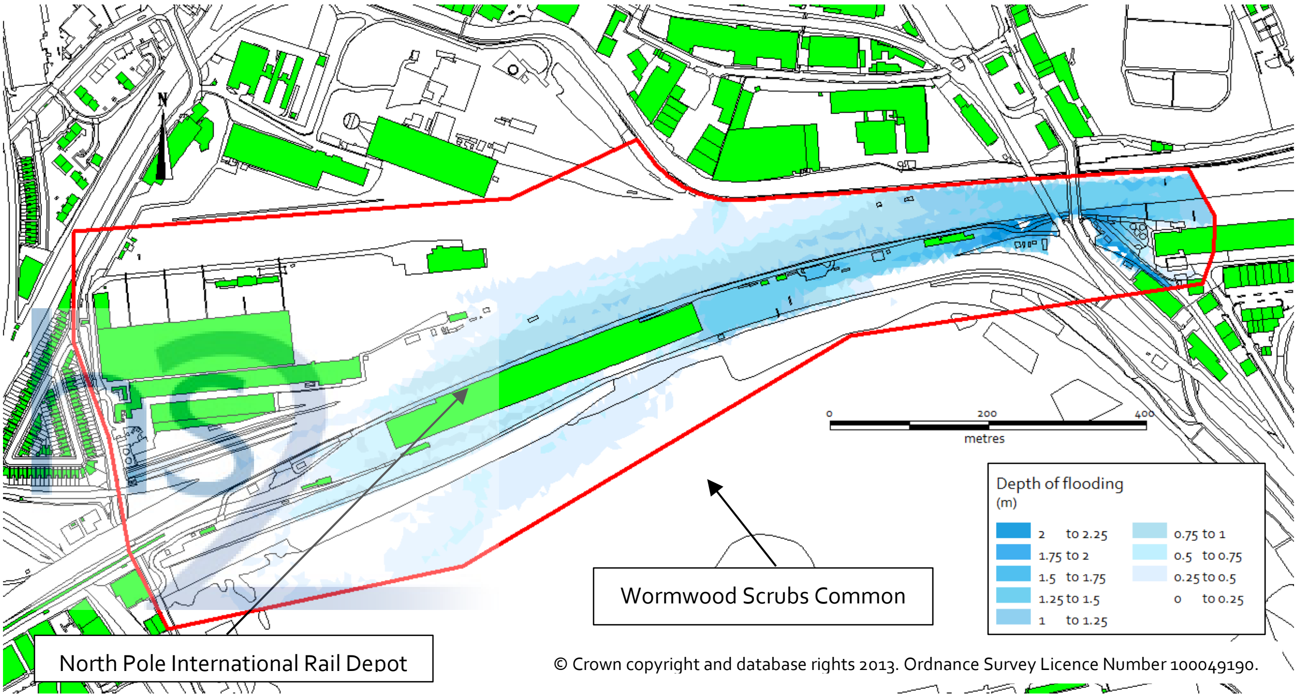
[4] R. W. A. Dun (2005), *An improved understanding of canal hydraulics and flood risk from breach failures*
[5] Tony L. Wahl, Dale J. Lentz (2011), Physical Hydraulic Modelling of Canal Breaches, U.S. Department of the Interior

4 Results

4.1 Extent and depth of flooding

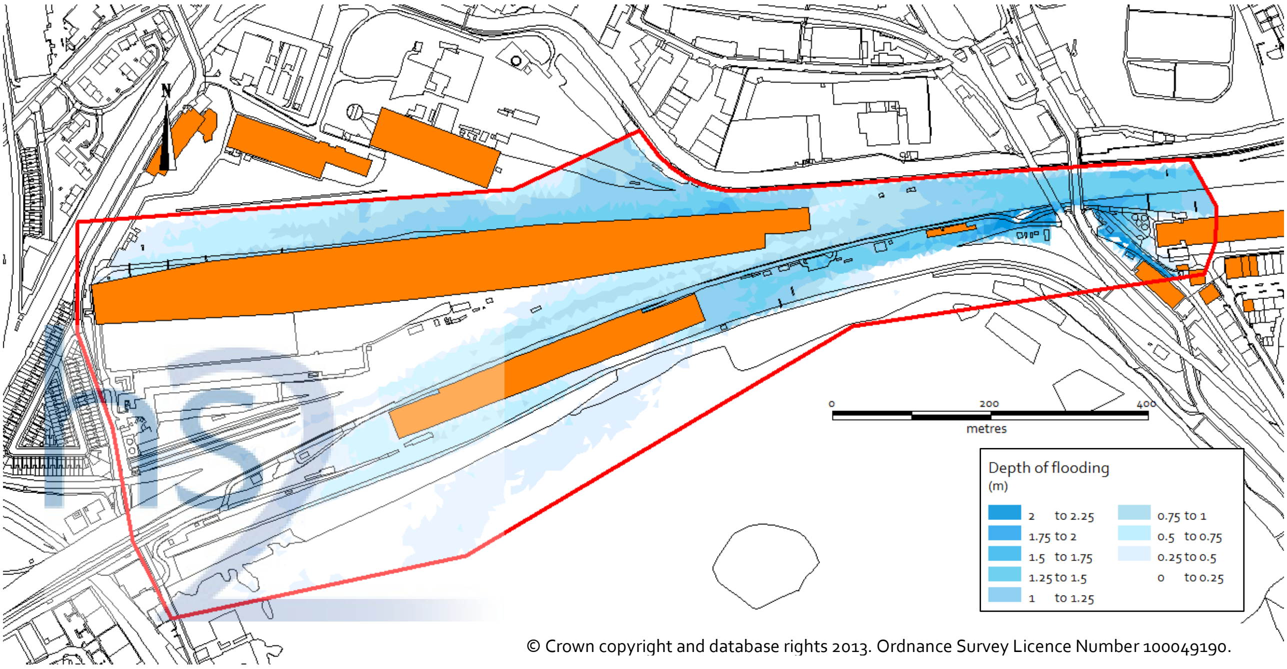
4.1.1 In all cases, flooding flows southwards from the breach location and then commences to fill the lower flat track-beds of the GWML. Flooding then propagates to the east and west, ponding in low lying areas. The primary flow directions out of the model area are to the south-west into Wormwood Scrubs Common and to the east along the GWML. Figure 5 shows the maximum flood extents for the existing condition model. The flooding over Wormwood Scrubs Common is relatively shallow compared with the flood depths within the GWML. The North Pole International Rail Depot and the raised ground at the northern extent of Wormwood Scrubs Common are shown to restrict flow onto Wormwood Scrubs Common.

Figure 5: Maximum flood depths for the existing condition



4.1.2 For the construction scenario, as shown in Figure 6, flood water from the 85m^3/s (20m wide) breach is shown to be restricted by the relatively narrow passage between the existing canal retaining wall and the station box. By representing the excavation as a block in the two-dimensional mesh there is no way for flood water to enter the excavation. This is a conservative assumption and has given rise to the maximum depths at the wall of the station box excavation. The flow restriction causes a 'backing up' of flood water to the north of the station box, with flood water extending a significant distance along the northern boundary. There is little change in the extent of flooding beyond the Old Oak Common station excavation.

Figure 6: Maximum flood depths for the construction phase



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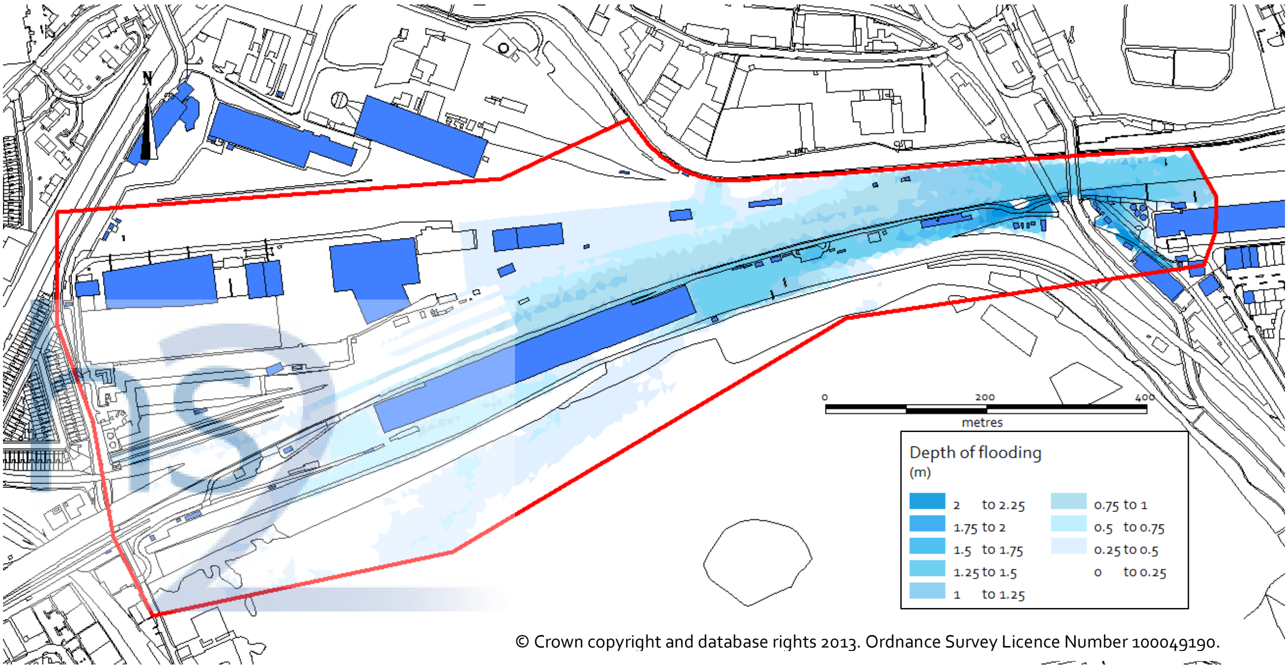
4.1.3 Figure 7 presents the maximum depths of flooding for the 85m^3/s breach in the operation phase. In this situation, the station box excavation has been covered, with permanent built structures above the box for the station and ventilation and intervention shafts. In addition the final ground level above the eastern third of the excavation will be lower than the existing ground level. The results of this can be seen in the figure below where the extents of flooding are sharply defined. The station building itself is not located within the extent of flooding.

Figure 7: Maximum flood depths for the operation phase



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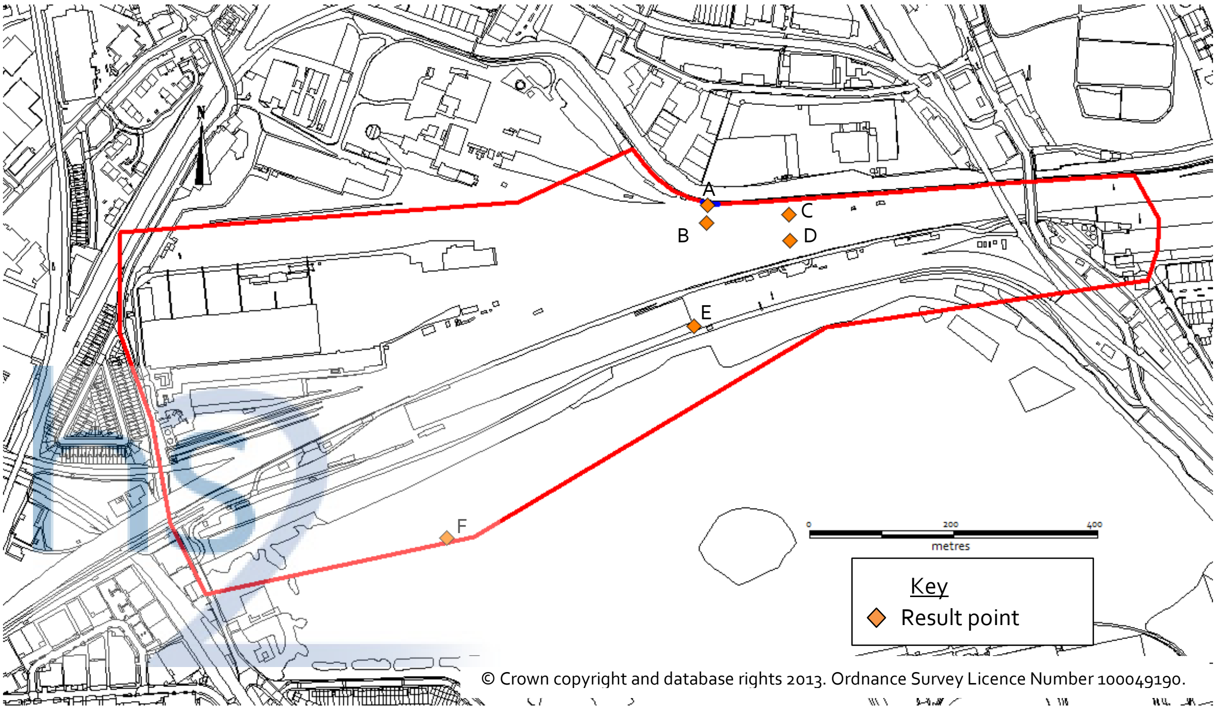
4.2 Flood depth results points

4.2.1 Flood depth hydrographs were also obtained at six locations within the study area (A-F) for all modelled cases, the locations of which are shown on the plan in Figure 8.

Figure 8: Location plan showing two-dimensional results points



4.2.2 Flood depths were extracted from the hydrographs for each of the conditions. Peak flood depths for the existing, construction, and operation conditions for the 85m^3/s, 50m^3/s and 17m^3/s breach events can be found in Figure 9,

4.2.3 Figure 10 and Figure 11 respectively. The greatest depths of flooding are along the northern face of the station box (location B) and also where there is a constriction as the flood flow passes the North Pole International Rail Depot (location E).

Figure 9: Maximum flood depths at results points A-F for 85m³/s breach

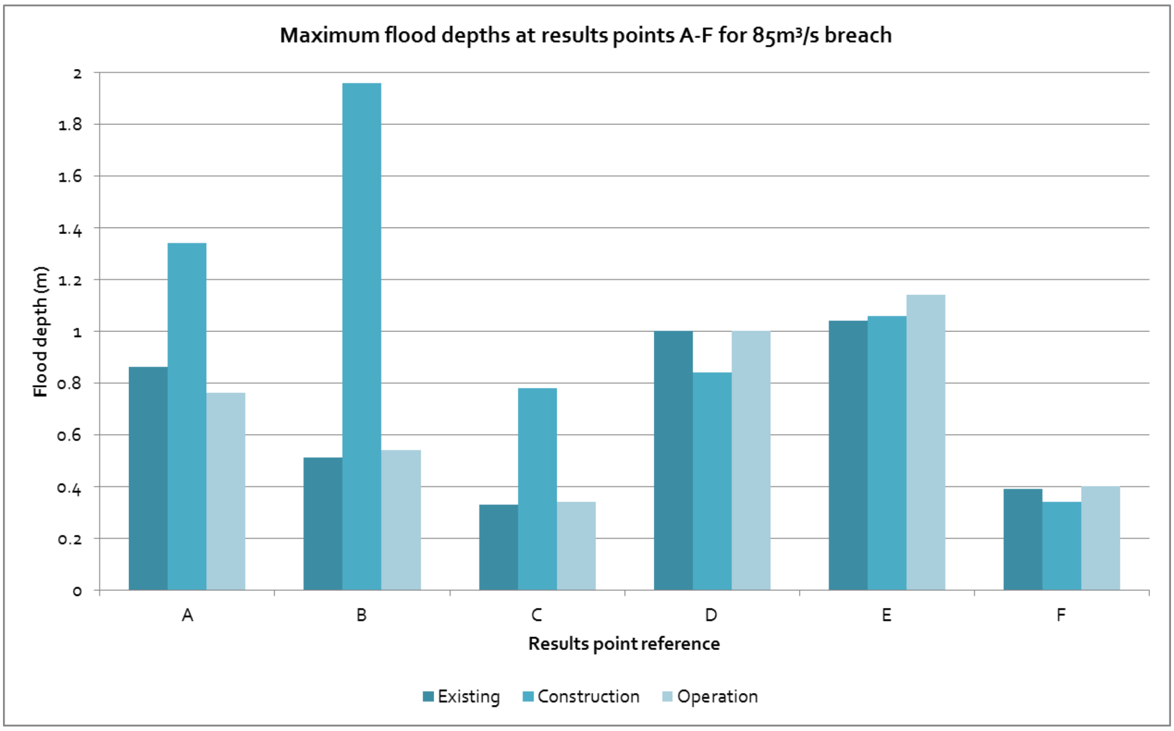


Figure 10: Maximum flood depths at results points A-F for 50m³/s breach

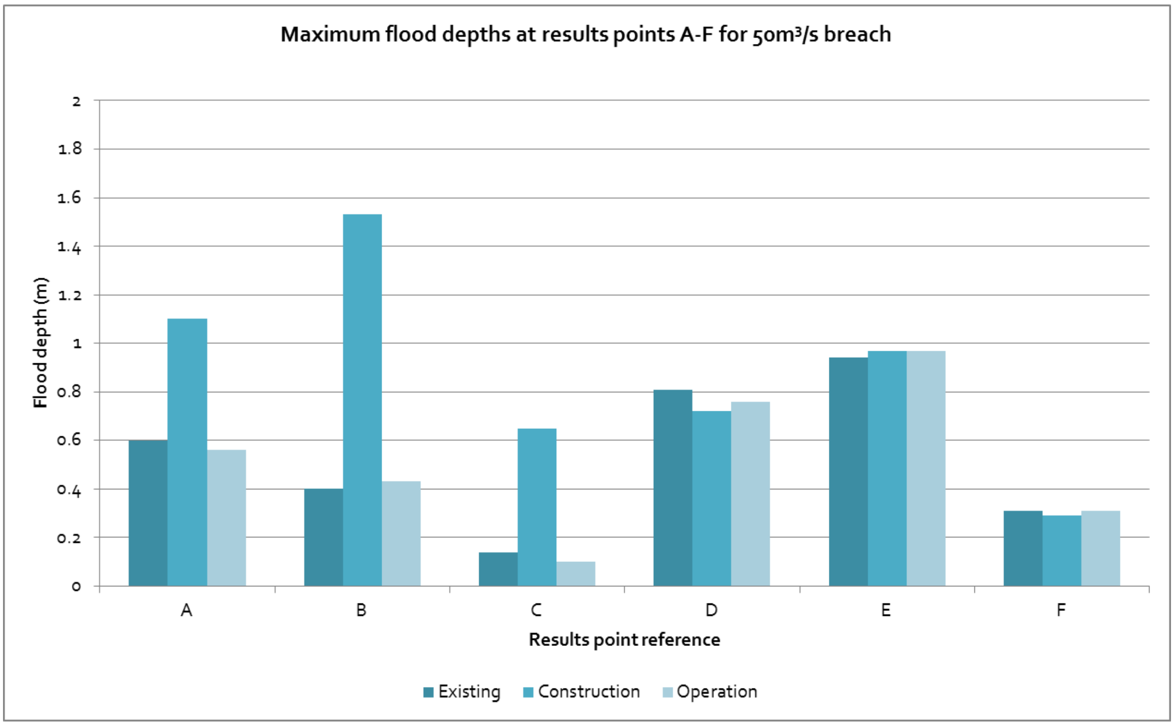
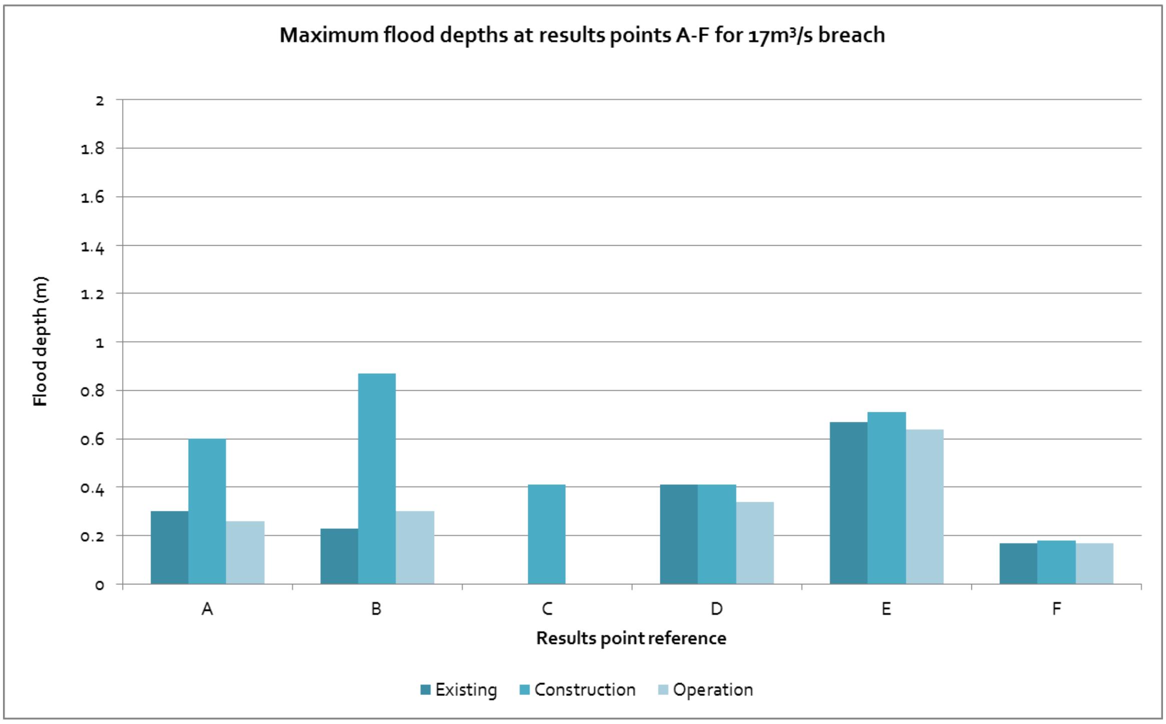


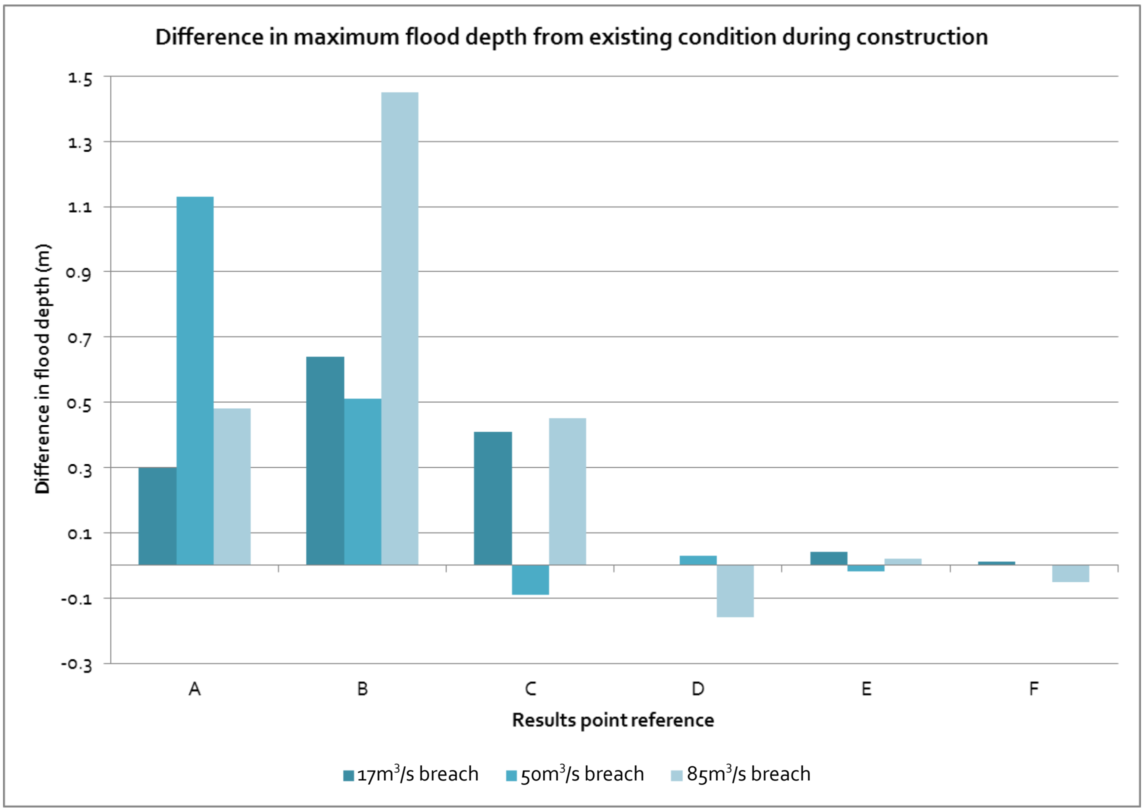
Figure 11: Maximum flood depths at results points A-F for $17m^3/s$ breach



4.2.4 As shown on Figure 9, during construction the deepest areas of flooding are to the immediate north of the proposed excavation (location B) where flood depths of over 1.9m are predicted for the 20m wide breach. This is due to the restriction to overland flows caused by the station box with the natural topography causing surface water to back-up north of the box.

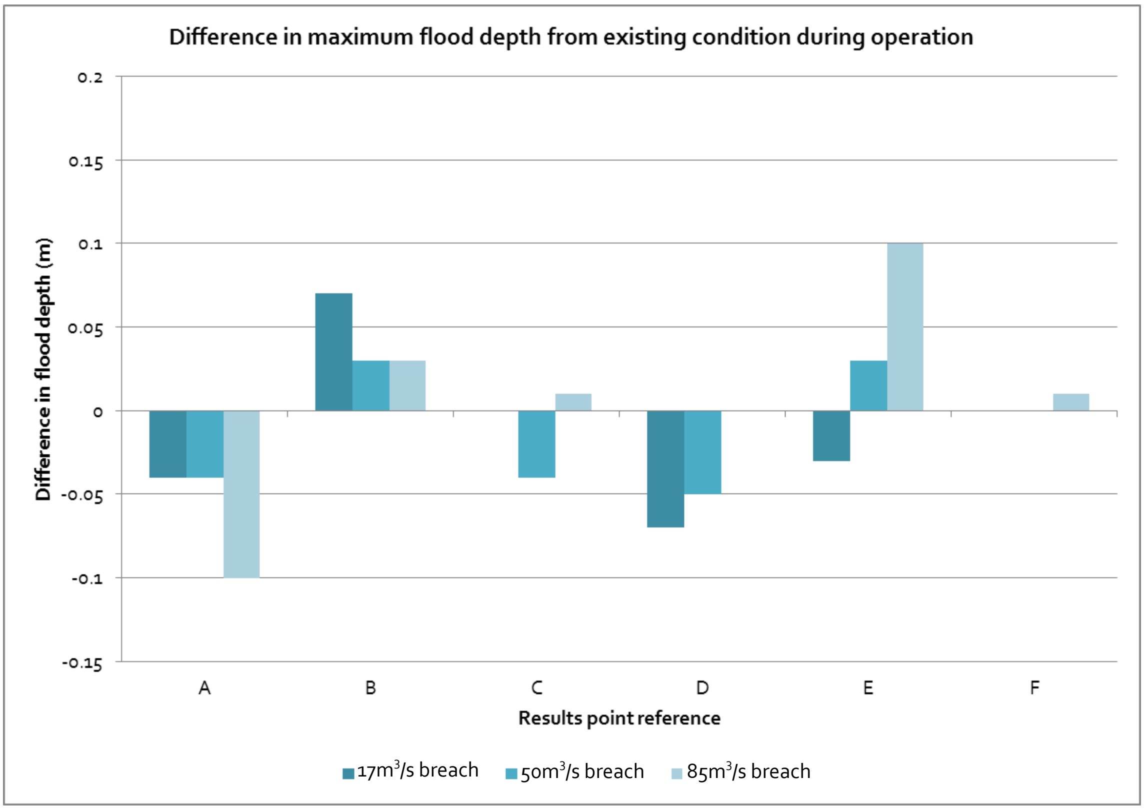
4.2.5 Figure 12 presents the difference between flood depths from the existing case to the construction case. It can be seen that the most substantial differences in flood depth are to the immediate north of the proposed excavation. Increased flood depths of up to 1.15m are seen at location A and increases of up to 1.45m are seen at location B. There is shown to be a reduction in depth of flooding at locations C to F for some breach events as flood volumes are attenuated north of the station box.

Figure 12: Difference in maximum flood depths from exiting condition at each reference location for 17, 50, and 85m³/s discharge hydrographs during construction



4.2.6 The differences in flood depths for the operation case are less significant, with variations less than 0.1m (100mm) in all locations, as shown in Figure 13.

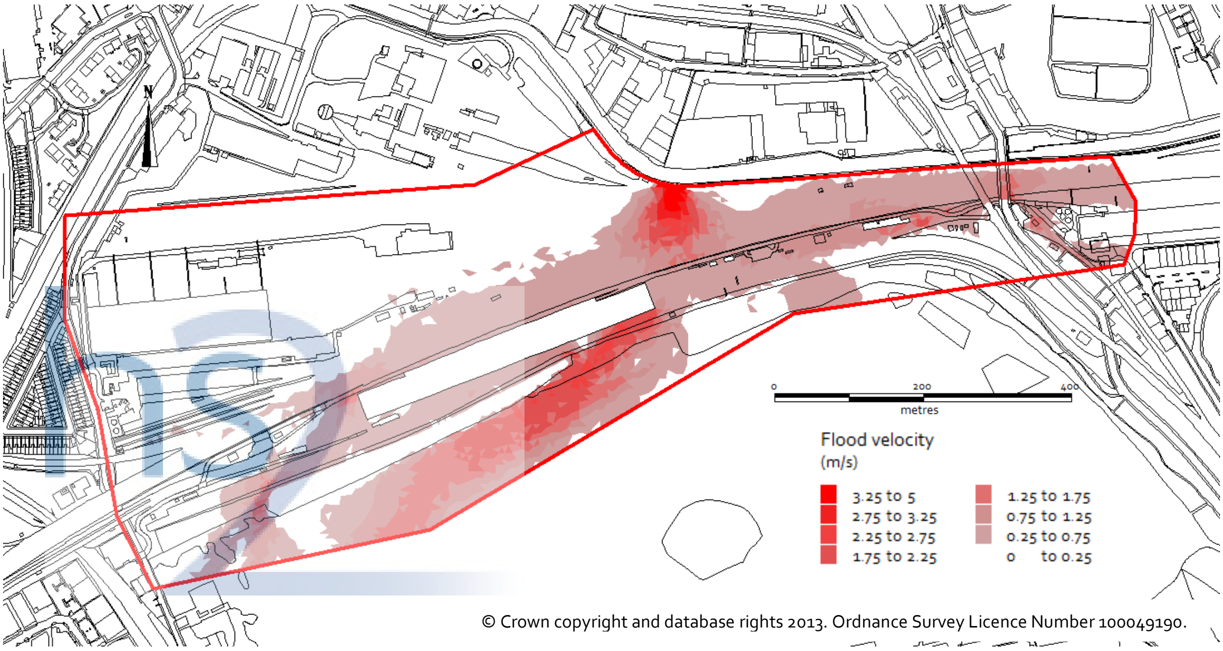
Figure 13: Difference in maximum flood depths from exiting condition at each reference location for 17, 50, and 85m³/s discharge hydrographs during operation



4.3 Flood velocities

4.3.1 In the construction phase, high velocities (>2m/s) will be realised immediately downstream of the breach (deep flooding 1.3-2m), and also to the south of the North Pole International Rail Depot as it flows onto Wormwood Scrubs Common and beyond (shallower flooding 0.4–1m). The velocity of flooding during the existing case is provided in Figure 14.

Figure 14: Flood velocity during existing condition for 85m^3/s breach



5 Calibration and validation

5.1.1 Modelling has not been previously undertaken in this location and therefore there are no data available to compare the results. A manual check of the results at a number of locations was undertaken to ensure that the representation of the ground surface was appropriate.

5.1.2 One of the variables in the modelling of flow over the ground surface is the representation of losses due to infiltration. There is the ability to represent infiltration in InfoWorks ICM. As the model does not represent rainfall, the only infiltration technique available is the Horton Infiltration method. A comparative model was undertaken for the breach during construction, the results of which are shown in Table 1. Conservative values of the Horton variables were used in the modelling (as the predominant ground cover in this area is railway ballast and therefore pervious). There is very little difference in the maximum flood depth at all of the results points. This is due to the quick time to peak of the breach hydrographs and the high depths relative to the infiltration capacity of the ground.

Table 1: Comparison of maximum flood depths at results points during construction for 85m^3/s breach with and without infiltration

Results point	Maximum flood depth (m) excluding infiltration	Maximum flood depth (m) including infiltration	Difference (m)
A	1.34	1.34	0
B	1.96	1.96	0
C	0.78	0.77	-0.01
D	0.84	0.83	-0.01
E	1.06	1.05	-0.01
F	0.34	0.33	-0.01

5.1.3 To be conservative the rate of infiltration was therefore assumed to be zero in all model scenarios.

6 Conclusions and recommendations

6.1.1 There is a residual risk of flooding to the proposed Old Oak Common station from failure of the Paddington Branch of the Grand Union Canal wall to the north of the Proposed Scheme.

6.1.2 The construction phase is most critical when considering both the flood risk to the Proposed Scheme as well as the impact of the Proposed Scheme on the risk of flooding elsewhere. The excavation for the Old Oak Common station box will be located immediately to the south of the chosen breach location where the settlement contours for the excavation of the station box are shown to intercept the retaining wall.

6.1.3 The proposed Old Oak Common station excavation will have a raised perimeter wall to prevent flooding of the station box and this perimeter wall will result in an increase in flood depth between the breach and the station box. Maximum flood depths in this area will reach 1.95m; the depth, however, varies around the station box and for the width of the breach.

6.1.4 The modelling has shown that there will be no significant change in the depth or extent of flooding to local receptors beyond railway land to the south of the Proposed Scheme. During construction there will be a reduction in the depth of flooding south of the station box in the event of a failure of the retaining wall, as the flood water will be attenuated between the perimeter wall and the existing retaining wall.

6.1.5 Velocities of flood water have been shown to be highest immediately after the breach location, and additionally where the flood water enters Wormwood Scrubs Common to the south of the Proposed Scheme.

7 Assumptions and limitations

7.1.1 The following assumptions were used during the modelling of the breach of the Grand Union Canal (Paddington Branch) at Old Oak Common:

- the 20cm LiDAR provided is representative of the ground surface and there have been no subsequent changes to the ground profile;
- the shallow water equations as described by Alcrudo F. and Mulet-Marti J. (2005)[6] apply in this situation; and
- the inflow hydrographs are representative of an actual breach.

7.1.2 The limitations to the hydraulic model include:

- no topographic survey has been undertaken;
- no calibration of the model due to a lack of actual breach event data; and
- the computation mesh was not extended beyond the extents of the LiDAR.

[6] Alcrudo F. and Mulet-Marti J.(2005), *Urban inundation models based upon the Shallow Water equations*. Numerical and practical issues Marrakesh July 2005. Proceedings of Finite Volumes for Complex Applications IV. Problems and Perspectives. Pages 1-12. Edited by: F. Benkhaldoun, D. Ouazar, S. Raghay. Hermes Science Pub. 2005.

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R. W. A. Dun (2005), *An improved understanding of canal hydraulics and flood risk from breach failures.*

Tony L. Wahl, Dale J. Lentz (2011), *Physical Hydraulic Modelling of Canal Breaches*, U.S. Department of the Interior.

Alcrudo F. and Mulet-Marti J.(2005), *Urban inundation models based upon the Shallow Water equations*. Numerical and practical issues Marrakesh July 2005. Proceedings of Finite Volumes for Complex Applications IV. Problems and Perspectives. Pages 1-12. Edited by: F. Benkhaldoun, D. Ouazar, S. Raghay. Hermes Science Pub. 2005.